

The “unknown” Greek Paleoenvironment: Curriculum Proposals through an Infusion Model for Elementary School, Using Ammonite Fossils

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Abstract

In this study we introduce an infusion model to “inject” ammonites and ammonite fossils in current subjects of Greek primary curriculum. Paleontology and mainly fossils attract more and more elementary students and teachers, yet in Greece this trend is solely about dinosaurs, despite the fact that the most common Greek fossils are not dinosaurs, but ammonites. Ammonites can be found in large population and diversity inside Greek rocks, as these rocks were part of Tethys’ seafloor at their geological time. Apart from the informal sources of education, these science topics are excluded from elementary national curriculum, and leave the regional paleoenvironment and geological history practically “unknown” to students. Data collected through a pre-test study, in 558 students of 4th, 5th, and 6th grade confirmed the above belief. A post-test at the original sample, using an open ended questionnaire and students’ drawings, evaluated positively the infusion teaching model, whose core were the ammonite fossils.

Keywords: Ammonite fossils, Marine paleoenvironment, Elementary geoscience education, Infusion model, Curriculum proposals.

Introduction

Paleontology and fossils are among science topics that are sometimes excluded or most times limited in primary school curriculum. Lewis and Baker (2010) mention that, Earth and Space Science (ESS) is limited, even in the high school curriculum, despite the fact that National Science Education Standards (NSES) give equal emphasis to ESS, in comparison with other scientific topics. Additionally, Cheek (2010) claims that, also in terms of scientific conceptions, there is comparatively less literature in geosciences than in other topics. However it must be considered that, in modern society, teaching and learning are taking place not only inside, but also outside the school classroom. TV programs, the Internet, educational toys, science kits, books, DVDs are all sources of informal education, especially for topics that are not included in the “formal” education; such is the school curriculum. Trend (2005) records the children’s interest in geological past and changes of the Earth and also found that this interest is greater in 11-to-18-years than in 8-to-12-

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years. Geology, paleontology and fossils, attract more and more children in Greece as well, yet this trend is mainly focused on dinosaurs. But what does Greece really have to do with dinosaurs? Dinosaur fossils cannot be found in Greek rocks, as Greece during their prehistoric era was a part of Tethys Sea. Therefore, no dinosaurs could have lived in Greece during that geological era. From this point of view, the Greek students should be at least informed and interested not only in dinosaurs, but also in the Greek prehistoric animals, the ammonites. This could be very useful in terms of education practices, as Greek students could study ammonite fossils, in situ like real paleontologists. Ammonite fossils and marine fossils, as learning tools, could provide students and teachers with the opportunity to connect education with the regional topography and geological history.

Greece is located in a geologically active region and most of Greek population experiences earthquakes at least once in their lives, yet Earth science education is not a major point in the national curriculum. Absence of ammonites in informal sources of education can be explained by the fact that dinosaurs are a more “trendy” and commercial topic than ammonites. But this cannot explain why the most common Greek fossil is not even mentioned in textbooks of any lesson at the primary Greek curriculum. For the history, a simple reference can be found only in 2002 geography textbook of 5th grade, which has though been revised and does not include this information in its current version. As pointed out by Klonari and Koutsopoulos (2005), in Greek schools, Geography is considered a boring, descriptive subject. Consequently, a great opportunity for an experimental approach of the geological history and geo-environment of Greece is lost for the Greek students.

As recorded in projects during the last decades, a common pedagogical practice, to introduce palaeontology topics is the use of dinosaurs (Burr, et al., 2003). Granted all the above, ammonites, the most common Greek fossils, are chosen as the topic of this project. This choice also aims at contributing the Greek students’ geo-cognition, the term that blends in the best way, geosciences with the mental processes of cognition, and refers to how they think and understand Earth and the processes on it. (Libarkin, 2006) Introducing ammonites to students and teachers can start from their interest in dinosaurs and be extended to many more geology topics, such as fossils and geological time. Dodic and Orion (2003) also suggest the use of fossils as concrete evidence and learning tool of difficult and abstract terms, such as geological time and evolution.

As it does not seem realistic to expect an immediate addendum of the national curriculum, an effort is made towards designing activities that can be conducted during the existing school subjects. Using an infusion model, ammonites and fossils are “injected” in all current subjects of Greek elementary school like Mathematics, Greek language, Geography, Music, Art, Environmental and Physical Science. Consequently, this study provides in service teachers with a variety of suggestions and ideas to choose from, as the most suitable for their class, accompanied with the basic scientific information. Harlen and Holroyd (2007) tabulated that teachers with low understanding and confidence on science tend to avoid teaching specific subjects as much as they can. They also point out, that teachers who adopt these “coping” strategies, also avoid discussion and activities eliminating the risk to expose their lack of knowledge. Lewis and Baker (2010) address the lack of qualified teachers, regarding geosciences, in the United States. Unfortunately, this is a reality in Greece as well, as the Greek primary school teachers during their studies in most of the universities do not attend the required courses related to Geology and Geography. These courses, are often optional lessons to choose. Though referring in first year university students, it is worth noticing that Orions et al. (1997) indicate a strong relation between Earth Science and spatial visualization ability. They also suggest that exposure to Earth sciences can influence positively their abilities in other sciences, like

Mathematics and Physics. All these are benefits lost for future teachers of Greek schools and possibly for their students too.

Greek ammonites: A brief background

Ammonites were carnivore marine cephalopod mollusks, with a decorated shell, in a variety in diameter, of few centimetres up to 2.5 m wide. Figure 1 presents an ammonite model and gives an idea of the extinct animal. Multiple diaphragms divided their shell to inner chambers. The animal itself lived inside the latter chamber. (Castro & Huber, 1999) Ammonites dominated prehistoric seas from Ordovician (485-443 mil. years ago) to Cretaceous (145-66 mil. years ago), at the same geological time that dinosaurs dominated land, thus they are considered very successful in terms of evolution. Ammonites, like dinosaurs, went extinct, due to the meteorite crash on Earth's surface 65 mil. years ago, known as the K-T event. (Monks, N., 2002)

At present, ammonites can be found only as fossils (Fig. 2). Their name comes from their shape's similarity to the horns of ancient Egyptian god Ammon. Ammonites are index fossils of the Mesozoic era (252-66 mil. years ago) as they can be easily identified; also they are widespread and they reveal a fast evolution rate (Sabyasachi, et al., 2004). According to Aubouin's theory, Greece, during the Triassic period (200 mil. years ago), was part of the hypotropical Tethys Sea. Ammonite shells and marine skeletons were trapped and fossilized, during the process of sedimentation. As a result, several marine fossils and especially ammonite fossils can be found in rocks all over Greece, even on the mountains. (Pope, et al., 1998; Raup, 1994). The most common Greek ammonites are the Carboniferous Permian ammonites of Parnitha, Hallstatt ammonites at the limestone of Chios, the ammonites of Othrys Mountain, Epidauros ammonites at the Peloponnese, and ammonites of Ammonitico Rosso (lower Jurassic) at Corfu, Lefkada, Epirus and Argolida. (Ministry of the Aegean, 2002). Ammonite fossils are the most commonly found fossils in Greek rocks and reveal clearly and briefly the regional geological history and paleoenvironment.



Figure 1. *Ammonite model, from the writers' private collection.*



Figure 2. *Ammonite fossil, from the writers' private collection.*

Significance of the study

This project can be considered as the first attempt to investigate primary students' beliefs and possible misconceptions about the most common Greek fossil, the ammonite. From that starting point, a prototype effort is made to produce evaluated teaching material about Greece's paleoenvironment, using ammonite fossils as a teaching tool. This approach is towards the directions proposed by Libarkin and Schneps (2012), as it encourages the understanding of the Earth's past from modern observations. Advantage of this material is also considered the fact that it can be applied in any lesson of the existing curriculum, thus it can be well adapted in the average school reality. Also, it can be considered as a basis for a new geoscience curriculum, which would encourage children's retrodictive reasoning.

Method

Research design

As pointed out, the "heart" of this geoscience teaching approach will be the ammonites, as the most common and representative Greek fossil. Ammonite fossils can quickly reveal and prove, in the most convincing way to students' eyes, the fact that Greece at the dinosaur era was the seabed of the prehistoric Tethys Sea.

Researchers intent to investigate, firstly if ammonites are really unknown to Greek primary students. This is strongly suspected, due to their absence from the national curriculum. This is the first research question and thus the starting point of this project. Consequently, this study intents to find out if ammonites could be used as a teaching tool, "injecting" geosciences in existing lessons of the national curriculum through an infusion model, which is the next research question to be answered. The researchers have chosen this kind of model as a first teaching approach of this topic to Greek primary schools, considering certain advantages, such as no need for equipment, additional costs, special time scheduling, teachers' and students' prior knowledge. Finally, the last research question would be the evaluation of the effectiveness of this teaching approach on students' possible geoscience misconceptions and gain of new knowledge on the Greek geo-environment.

Prior to designing the teaching model, it was necessary to take into consideration the students' former knowledge, alternative ideas and possible misconceptions about ammonites. Given that no literature was found at this exact topic, the study of their prior

knowledge was piloted in a 5th grade class of 22 students. After getting a positive feedback of the research instrument, a pre-test study was conducted on the study group. Parts of the infusion model designed for the aims of this study were then applied to the whole group of participating students and then evaluated through a post-test study. The whole research design consists of 5 steps, described below as Steps A to E.

Study group and ethics

The 558 students (n4th grade=182, n5th grade=186, n6th grade=190) participating in this project were recruited from five different urban elementary schools of Daphne, Helioupoli, Pallini, Kaisariani and Zografos. These areas are of middle economic standards, at Attica (Athens) major area, thus the sample is considered homogeneous regarding this aspect. The study was conducted within 27 classes, nine of each 4th, 5th and 6th grade.

As the participants were children, thus parts of vulnerable groups, the researchers paid special considerations in ethical issues. The objectives of the research and the purpose of each task (i.e. pre-test visit, curriculum proposal application and finally post-test visit) that was taken with the children were communicated with the school's principal, the teachers of the school, and the legal guardians of students. Researchers also got the consent for taking pictures during the activities, informed and got consent of the children themselves to participate in this study. They also avoided showing children's faces in photos taken during the project.

Research instruments and data collection method

During both pre-test and post-test studies, the researchers used the students' drawings and open-ended questionnaires. This kind of research instruments were considered the most appropriate to access students' conceptions and prior knowledge of the ammonites via the pre-test and, in the same way, evaluate the teaching model via the post test. Data obtained from the above questionnaires was analyzed for frequencies using SPSS.

As mentioned above, the whole research was conducted in five steps, described below:

Step A: Alternative ideas

For the purposes of this paper, we focus on alternative conceptions related to ammonites and fossils, because we intend to use them as the main teaching tool in our infusion model. The fact that analysis and understanding of the students' perceptions ensures better designing of action plans in geoscience education is also mentioned by Lewis and Baker (2005). Students were asked to express their knowledge and alternative ideas about ammonites, in an open-ended questionnaire. The two questions were: a) «What is an ammonite?» and b) «Have you ever seen an ammonite? If yes, where?». The first question aimed to reveal students' possible existing knowledge or misconceptions about ammonites. The second question intended to investigate the possible sources of information and knowledge students have had about ammonites. The fact that questions were chosen to be open ended, helped the students to express their beliefs and ideas, the way they would prefer and get as analytical as they wished.

Step B: Drawings

Students were asked to draw an ammonite. No picture or ammonite model was presented to them prior to that. Steps A and B were conducted after scheduled visits of the researchers at the 27 different classes.

Step C: Developing the infusion model

An effort was made to create a variety of ammonite/fossil teaching activities that could be chosen by in service teachers and be applied in lessons of the current curriculum. These activities form the infusion model to teach the palaeoenvironment of Greece, using ammonites and fossils. Attention was paid to create a complete model, not only for the aims of the present study, but a teaching tool available to serving teachers, ready to be used at any time of the school year. The methodology idea is borrowed by infusion and multidisciplinary models proposed for developing environmental education curriculum (UNESCO-UNEP, 1994). The primary goal of the whole model is a basic understanding of the Greek geo-environment, through tangible “evidence”, such as the most common Greek marine fossils, ammonites. Additional goals would also be for the students to: (a) built a basic vocabulary and background knowledge about Greek geo-environment, (b) get familiar with basic geoscience terms such as rocks and fossils, (c) understand that the environment they live in is a changing system through geological time and (d) understand what palaeontology and geology are about and their connection to other sciences.

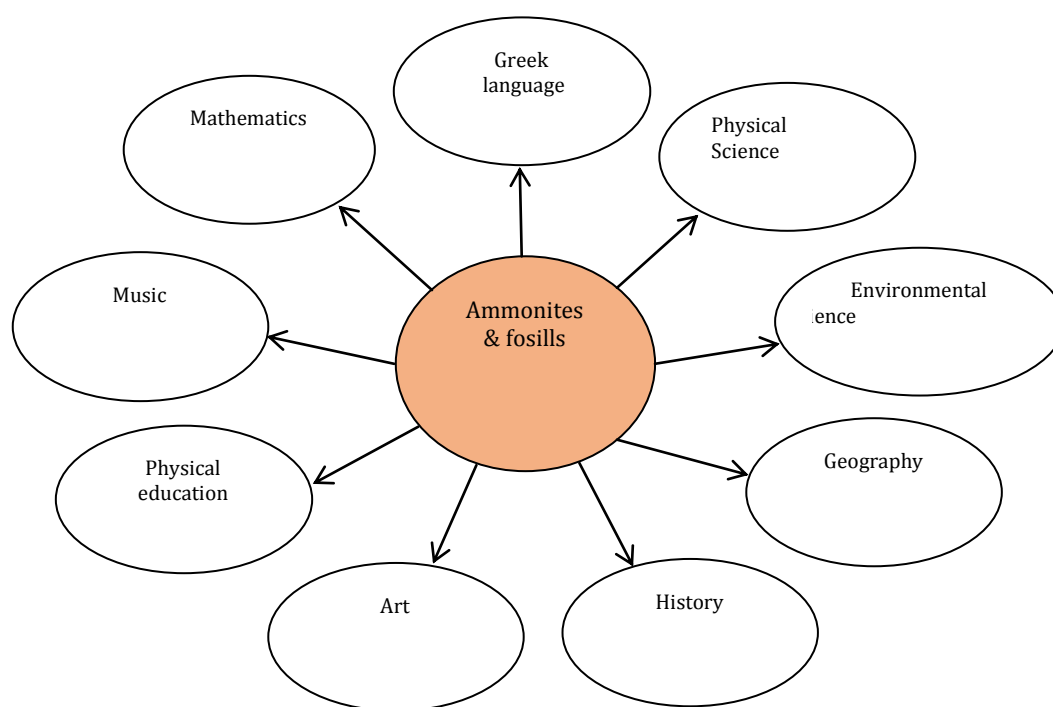


Figure 3. Structure of the infusion model designed in step C.

The variety of activities offer a great deal of flexibility for the in service teacher in choosing how to present the information about ammonites and fossils. Following the goals of the national curriculum, the suggested activities intend to cultivate a variety of skills, besides gaining new knowledge, such as oral presentation, reading, writing, use of mathematical functions, problem solving, and working in groups. Particular attention was given, so that the infusion model would be well tailored and applicable to Greek school reality, thus it can be conducted during any school day, with everyday materials. Additionally, all activities are connected to existing topics and specific lessons of the national curriculum. During Step C, the teaching material was forwarded to two primary school administrators, for review and comments. Considering their reviews and after improving parts of it, its final structure resulted in the teaching proposals/exercises organized in three main

groups and summarized in Tables 1, 2 and 3. Groups 1 and 2 include proposals for ammonite infusion in Greek language and Mathematics respectively, as these two lessons represent more than half of the daily schedule in Greek schools. Group 3 includes teaching suggestions to "inject" ammonites and fossils in all other lessons of the 4th 5th and 6th grade curriculum. All following exercises of Group 1, 2 and 3 were fully described and detail presented in a 30-page teacher's textbook, in Greek. This textbook also included a brief geoscience background with all the basic information and images about geologic time, Tethys Sea, ammonites and fossils. All students' sheets, maps and images were also included in an appendix, to be photocopied and ready for use.

Group 1: Infusing ammonites and fossils in Greek language lesson

Basic information and geosciences terms can be given through vocabulary and grammar exercises and activities, similar to these found in Greek language textbooks. The 15 different types of exercises, presented in Table 1, dealt with three main topics: grammar, vocabulary & composition and finally reading. The complexity and difficulty of given exercises and texts varied significantly, depending on grade. Exercises are similar to these given as daily homework to Greek students.

Table 1. *Infusing ammonites and fossils in Greek language lesson*

Topic	Exercise/Activity
Grammar	<ol style="list-style-type: none"> Convert the following sentences from active to the passive voice and vice versa: "Ammonites dominated the prehistoric sea of Tethys." or "Paleontologists found ammonite fossils in the mountain's rocks." Convert the following sentences from direct to indirect speech and vice versa: The paleontologist said: "Fossils prove that ammonites dominated the prehistoric sea of Tethys." Find if the given nouns are a "He", "She" or "It": ammonite, rock, fossil, Tethys etc. (in Greek the ammonite is a "he", Tethys is a "she" and fossil and rock are both "It"). Rewrite the sentences by changing the verbs from present simple to past simple: "Ammonites dominate the seas, like dinosaurs dominate the land" Rewrite the sentences by changing the nouns to plural: The paleontologist found an ammonite fossil during the excavation in a mount of Peloponnese. Fill the gaps with the right form of the verb given in the parenthesis: 65 million years ago, a meteorite <u>crushed</u> (crush) on Earth and ammonites, like dinosaurs <u>went</u> (go) extinct, due to climate changes. Write all the forms of the given nouns: ammonite, fossil, extinction (Greek nouns form four single and four plural forms). For each given noun write a suitable adjective in the right form: <u>prehistoric</u> sea, <u>rare</u> fossil, <u>big</u> ammonite. (Greek adjectives form four single and four plural forms, according to nouns). Place the given geoscience terms in alphabetical order: ammonite, fossil, extinction, paleoenvironment etc.
Vocabulary and composition	<ol style="list-style-type: none"> Make a geoscience pocket dictionary. Try to express your own definition for the given terms: fossil, marine fossil, ammonite, prehistoric etc. Crossword puzzle, containing all the basic terms of the ammonite and fossils topic. Find the given words inside the fossil cryptolex and use them in a logical way to create your own geological story. Create as many words as you can, using the prefix geo- and write a sentence with each one of them. (e.g.: geo-science, geo-environment, geo-logy) Writing compositions on the subjects: "Ammonite's fantastic 65.000.010th birthday party at the Goulandris Museum of Natural History." and "An ammonite's story and long journey from birth to the museum fossil exhibition."
Reading	<ol style="list-style-type: none"> Reading information texts of 300-800 words about ammonites were prepared as a reading exercise. Each text was followed by 3-5 reading comprehension questions. After reading, the students would be encouraged to express any query and discuss the comprehension questions.

Group 2: Infusing ammonites and fossils in Mathematics

Basic information about ammonites and fossils was “injected” in Mathematics through exercises, similar to these of the 4th, 5th and 6th grade Mathematics textbooks. Table 2 summarizes these exercises of graduated difficulty.

Table 2. *Infusing ammonites and fossils in Mathematics*

Topic	Exercise/Activity
Arithmetic exercises	1. <i>rite the numbers given at the sentences and vice versa: “Ammonites went extinct sixty five millions <u>65,000,000</u> years ago.” and “Ammonites dominated Tethys Sea 200.000.000 <u>two hundred million</u> years ago.”</i>
	2. <i>hich decimal value has 8 at each given number? “Ammonites appeared on Earth during the Ordovician period, between 485.400.000 and 443.800.000 years ago.”</i>
	3. <i>he biggest ammonite fossil found is 2.5 meters wide. Convert this diameter to cm, dm and mm.</i>
	4. <i>ill the missing information, with the given numbers rounded to the million: “Ammonites lived in Tethys sea during the Cretaceous period, which lasted (145,321,100) <u>145,000,000</u> to (66,542,000) <u>66,000,000</u> years ago.</i>
Problem solving	1. <i>Paleontologists found ammonite fossils in a great variety of sizes. The smallest one found has a 3 mm diameter. If the biggest one is 77,000 times bigger than the smallest one, how big is the biggest one? Find out and the result will really surprise you!» Critical thinking can follow, by asking the students to find objects with sizes similar to the smallest and the biggest ammonite, or answer questions like: “Was the biggest ammonite larger or smaller than two of our classroom’s desks?” or “How many of the smaller ammonite fossils would have the same area (in cm³) with the bigger one”. A constructivist discussion about personal units would also be useful, at this point. (Van de Walle, 2005)</i>
	2. <i>mmonites appeared on Earth approximately 400,000,000 years ago and went extinct 65,000,000 years ago, like dinosaurs. Sea turtles appeared approximately 245×10^6 years ago and still live on Earth. Is it possible that ammonites and sea turtles ever lived together at the prehistoric seas?</i>
	3. <i>he paleontologist Otto Schindewolf is an ammonite specialist and estimates that every shell spiral needs 18 months to be formed. Most found ammonite fossils have 12 shell spirals. Estimate the average ammonite life cycle in years.</i>
	4. <i>n the rocks of mountain Pindos, the paleontologists found an ammonite fossil with 6.2 cm diameter. Considering its shape as a circle, calculate its perimeter and area.</i>

Group 3: Infusing ammonites and fossils in Geography, Environmental and physical Science, History, Music, Art and Physical Education

Group 3 includes activities, which “inject” basic information about ammonites and fossils in every other lesson of the 4th, 5th and 6th grade, apart from Greek language and Mathematics. These activities are presented in Table 3.

Table 3. *Infusing ammonites and fossils in Geography, Environmental and Physical Science, History, Music, Art and Physical Education*

Lesson of the National Curriculum	Exercises/Activities
Geography	1. A blank map of Greece was prepared for the students, on which they could draw their own thematic map of Greek fossils, including the appropriate map legend. Students could consult their school atlas and a list of all Greek fossils found per area.
Environmental and Physical Science	2. Several environmental and science projects were proposed such as “Extinct animals”, dealing with evolution and adaption skills or “Who eats whom?”, an activity about the synthesis of a prehistoric food chain, including ammonites, their food and their predators. Groups should be encouraged to display and share their work with the rest of the class or the whole school, as food for thought and discussion.
History	3. The origin of the word Ammonite, is the suggested starting point for projects about ancient gods, tradition and beliefs, as in medieval Europe, ammonite fossils were considered as a lucky stone
Music	4. poem in rhyme (original written in Greek) was prepared for the students, describing the adventures of a small ammonite, which finally became a fossil exhibited in a famous museum. Students can be asked to sing it in different tempos and volume, while clapping rhythmically. The students can listen the suite “Le carnaval des animaux” (The Carnival of the Animals) Movement XII Fossils (fossils) of Charles-Camille Saint-Saëns. After that, they can be asked whether they liked it, if they thought it matched its title and try to identify the instruments that they heard, which are the piano, xylophone, strings and clarinet. Students should be encouraged to express their thoughts, impression and feelings about the musical piece. Finally, it is suggested to present them photos of the original manuscript of the composer, which includes his own fossil drawing.
Art	5. Students can be asked to create ammonite representations using collages and different drawing techniques, in order to show how the original mollusk looked like. Also an empty shoebox painted blue inside can be converted to a 3D prehistoric aquarium with lots of paper ammonites hanging in it. Finally, clay ammonite fossil replicas can be created and painted to look like the original ones, according to very simplified versions of fossil duplicate techniques for teaching purposes. (Waters and Savage, 1971)
Physical Education	6. A three-meter diameter shape of an ammonite can be drawn on the schoolyard with chalk for hopscotch game. Another proposed activity would be “Tethys chasing” between two student groups, “ammonites” and “mossasaurs”, the predators and common ammonite eaters of the prehistoric sea.

Step D: Apply of ammonite infusion model's teaching activities in classroom

The class teachers were provided with the infusion model textbook, which was presented to them by the researchers, in a brief 45 minutes presentation. The teachers of the participating classes were asked to apply the model, using one exercise/proposal from each one of the three groups, described in Step C. This practice ensured that every participating class would apply the model in Greek language, Mathematics and one more curriculum lesson, which was left free to be chosen. From that point, the teachers were flexible to decide and schedule, the time and specific chapter at which they chose to apply the model's teaching proposals. No former information about ammonites was presented to

the students prior applying the model. All the basic information about ammonites was given via the texts and figures of the given exercises. The researchers were present in the classroom in order to observe the participants' reactions, comments and possible difficulties. Researchers were also available for questions and clarifications, during Step D.

At the Greek language lesson, the students were given grammar exercise sheets, referring to the chapter they were taught at that time (e.g.: converting indirect to direct speech and vice versa). The exercises were adopted by the infusion model textbook and were given photocopied to the students to be answered individually. Similarly, the infusion model was applied in Mathematics, with mathematical problems, to be solved. The 3rd lesson from Group 3, applied in 6th grade classes appealed to the Art class. The students of 5th grade worked in groups of 4-5 and created thematic maps of Greek fossils during their Geography lesson, as the 5th Grade Geography curriculum includes the subjects of thematic maps, geopolitical and geophysical maps of Greece. Finally, the 4th grade students synthesized a prehistoric food chain, during the lesson of Environmental science, in accordance with the specific chapter about environmental food chains. The same students expressed their desire to create clay models of ammonites and clay replicas of ammonite fossils at home in order to decorate them.

Step E: Evaluating the model's efficiency

Approximately two months after the application of the model, the researchers visited the classrooms again, to investigate the efficiency of the model, using a post test. The 558 participating students were given at that time an open-ended questionnaire. Open ended questions were chosen at this step as well because, they would give the students the opportunity to add as much information and details as they wanted. The 1st question was: «What is an ammonite?» and intended to show the degree that students, gained or not the given information about fossils and ammonites. This question was followed by a request for a separate ammonite drawing, which would reveal if they could include correct details in their representations. The 2nd question was «Why do we find ammonites in the Greek mountains?» and intended to reveal or not students' ability to apply the gained knowledge into more complex issues. This question tends to investigate the students' ability to combine all the new information about ammonites in order to end up to conclusions about the changing environment.

Results and discussion

Step A, about students' former knowledge, revealed the alternative ideas students have about ammonites. Table 4 summarizes given answers to the 1st pretest open-ended question: «What is an ammonite?» and presents them grouped in five categories.

It is remarkable that no student of any grade mentioned that ammonites went extinct and can only now be found as fossils. Nor were the answers of older students much more correct or accurate than these of the younger ones. As expected, the majority (70.3%) of students claimed clearly that they have no idea of what an ammonite is. A significant number of students (4.8% and 15.1%) used the word's etymology in order to figure out what an ammonite could be. Consequently, the summation of the above three percentages (90.2%) shows that ammonites are practically unknown to the great majority of Greek students. Only the 9.9% of the students gave answers that contained correct information, such as the fact that ammonites were marine habitats (4.7%) and that they refer to a past geological time (5.2%). Table 5 presents the answers of 2nd pre test question: «Have you ever seen an ammonite? If yes, where?».

Table 4. *Frequencies of the students' answers, to the 1st pre-test question.*

Answers to the question: «What is an ammonite?»	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
I do not know	134	73.6	130	69.9	128	67.4	392	70.3
Ancient species of marine snail	10	5.5	10	5.4	9	4.7	29	5.2
Mollusk	2	1.1	8	4.3	16	8.4	26	4.7
Ammonia/chemical compound	6	3.3	10	5.4	11	5.8	27	4.8
Diamond/mineral/rock	30	16.5	28	15.1	26	13.7	84	15.1

The percentage of the students (84.9%) who claimed that they haven't seen an ammonite at all can be considered close and in agreement to the findings of the 1st pretest question, that 90.2 % of the students admit they do not know what ammonites are. Given answers presented in table 5 did not surprise the researchers, as Goulandri Museum of Natural History is the only well-known museum in Athens major area with an ammonite collection. Once again, the answers of 4th, 5th and 6th grade were close.

Table 5. *Frequencies of the student's answers, to the 2nd pre-test question.*

Answers to the question: «Have you ever seen an ammonite? If yes, where?»	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
I haven't seen one.	151	83.0	163	87.6	160	84.2	474	84.9
At Goulandri Museum of Natural History (Athens, Greece)	26	14.3	20	10.8	22	11.6	68	12.2
At a museum abroad	5	2.7	3	1.6	8	4.2	16	2.9
Sum of positive answers	31	17.0	23	12.4	30	15.8	84	15.1

At the last part of step A, students were asked to represent an ammonite. Drawings, that contained shapes similar or close to these of an ammonite fossil or animal, were counted as correct representations. Incorrect representations (Fig. 4) included totally irrelevant elements, such as rocks, geometric shapes, weather or landscape drawings.

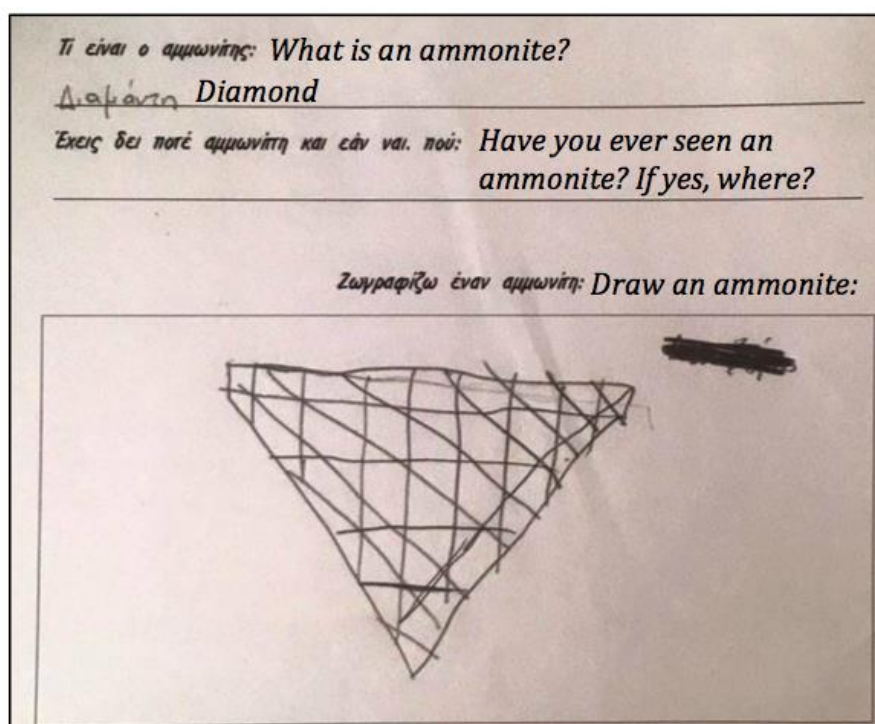


Figure 4. Incorrect pre-test answer and representation of an ammonite.
(English translation is added in the original picture.)

Findings of the pretest ammonite representations are presented in Table 6.

Table 6. Frequencies of the students' pre-test representations of an ammonite.

Ammonite representations	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
Correct representations	16	8.8	14	7.5	18	9.5	48	8.6
Incorrect representations	166	91.2	172	92.5	172	90.5	510	91.4

The percentage of the incorrect representations (91.4%) is also in agreement with the findings of the previous open ended questions, which showed that 90.2% of the students do not know what an ammonite is and the 84.9% admit they have never seen one. Figure 4, presents a characteristic example of a wrong answer at 1st pre-test question, accompanied by a corresponding drawing; revealing the student's alternative idea that ammonite is a diamond. This belief could be explained by the fact that the student hadn't seen an ammonite before, so the 3rd pre-test question is left blank.

It is far more obvious that ammonites, the most common Greek fossils, are practically unknown to Greek students, so a teaching effort would be noteworthy. As mentioned earlier, the teachers of the participating classes, at step D had the opportunity to choose the lessons they would apply the infusion model designed during step B. This freedom of

choice was left intentionally, as the authors believe that it would help towards a positive attitude of the teachers towards the model. The teachers' responses were very positive, indeed. They said it was useful for them, because not only did their students gain a correct perception about the environment in Greece during the dinosaur era, but them as well. They also denoted that a serious advantage of the model was that the activities, were not "about ammonites" but, gave the information, while dealing with the existing topics and goals of the curriculum. At that point we note that teachers of different specialties serve Music and Physical education in most of the Greek primary schools, so the activities referring to these lessons were not chosen by classroom teachers. Nevertheless, they said they found them interesting and advised us to propose them to their colleagues. Thus, the activities "injecting" ammonites in Music and Physical Education were not applied in any participating classroom. Figure 5 and figure 6 demonstrate exercises No, 8 and 12, from Group 1, answered by 4th and 5th grade students respectively. These figures give an example of the model application, during the lesson of Greek language.

IV) For each given noun, write a suitable adjective in the right form.
IV) Γράφω ένα επίθετο, που να ταιριάζει στο ουσιαστικό, στο σωστό γένος αριθμό και πτώση.

1. prehistoric ammonites 2. of the blue sea
1. πρωϊστοϊκοί αμμωνίτες 2. γαλάσιος θάλασσας
3. hard rock 4. sudden extinction
3. σκληρό πέτρωμα 4. ξαφνική εξαφάνιση

Figure 5. Grammar exercise, No. 8 from Group 1, answered by a 4th grade student. (English translation is added in the original picture.)

Ανακαλύπτω τις λέξεις της στήλης στο απολιθωμένο... κρυπτόλεξο. Με τις λέξεις που ανακάλυψα γράφω μία σύντομη ιστορία. Find the given words inside the fossil... cryptolex and use them in a logical way to create your own geological story.

Δ	Ε	Ι	Ν	Ο	Σ	Α	Υ	Ρ	Ο	Ι	Ο
Κ	Α	Δ	Η	Δ	Α	Μ	Τ	Γ	Ι	Ο	Θ
Κ	Α	Φ	Κ	Ζ	Φ	Μ	Ρ	Η	Τ	Υ	Θ
Ι	Δ	Α	Δ	Γ	Κ	Θ	Ε	Τ	Υ	Ρ	Θ
Δ	Υ	Γ	Τ	Ε	Μ	Η	Τ	Ο	Ο	Α	Α
Ε	Σ	Α	Φ	Α	Ν	Ι	Σ	Η	Ι	Ζ	Α
Α	Ι	Τ	Ε	Θ	Η	Τ	Β	Ο	Κ	Ι	Α
Δ	Ο	Μ	Ε	Ζ	Φ	Ι	Ρ	Μ	Ο	Ι	
Ε	Υ	Σ	Ε	Δ	Δ	Ζ	Ο	Υ	Δ	Ζ	Ο
Α	Δ	Ρ	Ε	Τ	Δ	Ι	Ο	Ι	Φ	Ρ	Η
Ρ	Γ	Α	Α	Η	Ε	Υ	Ζ	Ο	Η	Α	Τ
Α	Π	Ο	Α	Ι	Ο	Δ	Μ	Α	Τ	Α	Ο
Ζ	Α	Ζ	Σ	Β	Κ	Υ	Ρ	Τ	Ι	Ε	Δ
Δ	Σ	Ζ	Δ	Α	Θ	Τ	Ι	Α	Ζ	Ο	
Η	Φ	Ρ	Α	Δ	Ζ	Α	Ε	Α	Τ	Δ	Ι
Α	Τ	Α	Τ	Φ	Α	Α	Α	Α	Η	Ο	
Κ	Τ	Κ	Υ	Η	Β	Ζ	Τ	Η	Θ	Υ	Ζ
Ι	Ε	Θ	Ο	Ο	Ν	Φ	Η	Σ	Α	Φ	Η

Παλαιοντολόγος
Δεινόσαυροι
Αμμωνίτες
Εξαφάνιση
Ιουρασικό
Βυθός
Ταθής
Απολιθώματα
Μετεωρίτης
Οστρακό
Fossils
Meteorite
Shell

Πριν από περίπου 65.000.000 χρόνια εξαφανίστηκαν οι δεινόσαυροι.
Οι παλαιοντολόγοι έχουν διάφορες απόψεις, οι περισσότερες
έχουν πως η εξαφάνισή τους προήλθε από έναν μετεωρίτη.

Dinosaurs went extinct about 65.000.000 million years ago. Paleontologists have had different theories about this fact, but most of them believed that dinosaurs' extinction was due to a meteorite crash. Ammonites, like dinosaurs went extinct during the same time. Ammonites had shells that looked like snails. They had eight legs and lived at the seabed. Ammonites could also be found in Greece, which at the time was a part of the prehistoric "Tethys" sea. Nowadays, ammonite fossils can be found in the Greek seas. The period of time during which the dinosaurs went extinct was the end of the Jurassic period.

...ήταν απολιθώματα αμμωνιτών στις ελληνικές θάλασσες. Την περίοδο που εξαφανίστηκαν οι δεινόσαυροι τελειώνει και η Ιουρασική περίοδος, η περίοδος διαβόητη που ζούσαν οι δεινόσαυροι.

Figure 6. Vocabulary and composition exercise No. 12, from Group1, answered by 5th grade student. (English translation is added in the original picture.)

Figure 7 demonstrates the solution of the mathematic problem No. 5, from Group 2, solved by a 6th grade student, during a lesson about proportional variables.

το μικρότερο 3 χιλ. the smallest 3mm.	<u>Eugenia</u> . Name
το μεγαλύτερο 77.000 φορές μεγαλύτερο από το μικρό.	
The biggest is 77.000 times bigger than the smallest one.	
77/000	
* <u>3</u>	
231.000 χιλ = 231 μ. 231.000 mm. = 231 m.	
The biggest ammonite is 231 m.	
Ο μεγαλύτερος αμμόλιθος είναι είναι 231 μ.	

Figure 7. Problem solving exercise, No. 5 from Group 2, solved by a 6th grade student. (English translation is added in the original picture.)

Figures 8, A and B demonstrate two different solutions of the mathematic problem No. 6, from Group 2, solved by two 6th grade students, during a lesson about mathematical operations between large numbers. The first student (Fig. 8A) solved the problem as expected by the schoolteacher and in accordance to the lesson. The second student (Fig. 8B) gives a different graphical solution and answer. Also, as shown in Figure 8B, the student writes down “dinosaurs” in his/her solution instead of ammonites, as he/she might think that, as ammonites and dinosaurs went extinct at the same time, they also appeared at the same geological time on Earth.

Αμμόλιθοι εμφανίστηκαν πριν από 400.000.000 χρ.	Ammonites appeared 400.000.000 years ago.
Αμμόλιθοι εξαφανίστηκαν πριν από 65.000.000 χρ.	Ammonites went extinct 65.000.000 years ago.
Θαλάσσιες χελώνες εμφανίστηκαν πριν από 245.000.000 χρ.	Sea turtles appeared 245.000.000 years ago.
400.000.000	
- 245.000.000	
155.000.000 χρ. years	
Απ. : Οι χελώνες συναντήθηκαν με τους αμμόλιθους πριν από 155.000.000 χρόνια	Answer: The sea turtles met the ammonites 155.000.000 years ago.

A

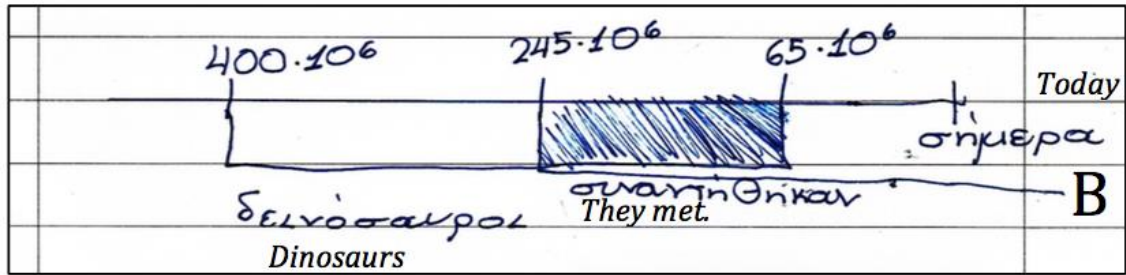


Figure 8. Problem solving exercise, No. 6 from Group 2, solved by two 6th grade students. (English translation is added in the original pictures.)

All 4th grade students enjoyed creating ammonite clay models (Fig. 9) during the activity No.5 of Group3.



Figure 9. Clay ammonite model activity No. 5, from Group 3, prepared by 4th grade student.

During step D, students showed great interest in the topic and were impressed by the fact that Greece, at that time, was part of a prehistoric sea. Many of the students were really hard to convince about the above fact. It seemed to them, really surprising, even impossible, that the place where they stand at moment, used to be underwater. Students' responses about ammonites and all geoscience information were remarkable as well. When ammonite pictures were presented at step D, many of them, claimed that they had already seen them. Characteristic expressions were:

- 6th grade student: «It is impossible that the ammonites are extinct! I have seen them!».
- 5th grade student: «I didn't know they are called ammonites, I knew a different name.»
- 4th grade student: «I have one at home!»
- 4th grade student: «They also have another name, I can't remember.»

The previous thoughts were expressed because students confused ammonites with nautilus, which are a common decoration in Greece. This confusion between ammonites and nautilus, seemed to be the most common misconception. Students quickly revealed an increased ability to express interesting thoughts and questions, which proved to be the perfect starting point for further discussion:

- 6th grade student, while solving the mathematics problem: «Were the smaller ammonite fossils originated from the youngest ones?»
- 5th grade student: «Is there any chance that even one family of ammonites survived the mass extinction and scientists will find their kids?»
- 5th grade student: «Why the ammonites did not swim away from the meteorite that hit Earth, to escape extinction?»
- 4th grade student, while preparing the ammonite clay models: «Did snails originally come from ammonites?»

Various facts about ammonites, like the size of the larger subspecies really impressed the students. Also, two of the 6th grade students wondered why their textbooks don't mention them and many students of all grades asked their teachers to organize a visit to a fossils/ammonites museum and a trip to a mountain for fossil hunting. The activities and exercises of the infusion model were given and presented by the school teachers, so most of the above students' questions were also answered by them. In some cases the teachers asked the researchers if they agreed with their answer or if they wanted to add any other information. The researchers had the minimum possible participation during step D, as the main reason for their presence was the recording of teachers' and student's reactions and comments. Neither the teachers nor the students found difficulties during step D. The students seemed to really enjoy the model activities of the Group 3.

As mentioned above, at step E the researchers visited again the 558 students, in order to evaluate the efficiency of the infusion model. Tables 7 and 8 present the students' answers to the 1st post test question. Answers, including correct information about ammonites were accepted as correct ones. It is remarkable that, after the infusion model application, the percentage of students, that knew what an ammonite is, improved significantly and raised up to 83.2% from the 9.9%, recorded at the pre-test. After model application, the great majority of the students, at least understood that ammonites do not refer to something inanimate, like rocks. To express that, they used the words animal, organism or creature. Both, 4th, 5th and 6th graders showed clear positive results, but it must be underlined that the higher the grade was, the more correct answers were given.

Table 7. *Frequencies of the students' answers to the 1st post-test question.*

Answers to the question: «What is an ammonite?»	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
Correct answers	142	78.0	149	80.1	173	91.0	464	83.2
Incorrect answers	40	22.0	37	19.9	17	8.9	94	16.8

Table 8 shows that, correct scientific details appeared in the students' answers, i.e. the fact that ammonites can now be found as fossils, the fact that they lived during past geological time and that they lived in a marine environment.

It is remarkable that nearly a quarter (23.8%) of the 6th grade students gave an accurate and fully descriptive answer on what an ammonite is. Over the half of the students pointed out that ammonites were marine and not land habitats. Also, as shown above, the 4th graders gave the simplest and least detailed answers. Regarding the correct answers given, it is noteworthy that some of the students included more than one correct information about ammonites, in their answer.

Table 8. *Frequencies of scientific content appeared in the correct students' answers to the 1st post-test question.*

Content of the correct answers to the question: «What is an ammonite?»	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
Fossilized animal*	33	23.3	33	22.1	17	9.9	83	17.9
Animal* of a past geological time	25	17.6	27	18.1	20	11.6	72	15.6
Sea animal*	27	19.0	24	16.1	9	5.2	60	13.0
Fossilized animal* of a past geological time	11	7.7	16	10.7	32	18.6	59	12.7
Fossilized marine animal*	17	12.0	16	10.7	30	17.4	63	13.6
Prehistoric sea animal*	12	8.5	13	8.7	24	13.9	49	10.6
Fossilized extinct sea animal*	17	12.0	20	13.4	41	23.8	78	16.8


*Also referred as organism, or creature

The 46.5%, is the summation of the frequencies of the answers: “Fossilized animal”, “Animal of a past geological time” and “Sea animal” and represent the percentage of students, whose answer included only one scientific information about ammonites, besides the fact that they refer to a living organism. A summation of the frequencies of the answers: “Fossilized animal of a past geological time”, “Fossilized marine animal” and “Prehistoric sea animal” shows that the 36.9% of the students managed to combine two scientific pieces of information about ammonites. This percentage appears even higher in 6th grade. After the model application, students could use geoscience terms such as fossils, rocks and geologic time. Five 6th grade students also mentioned that ammonites are different species to nautilus.

Students' post-test drawings were also very revealing and showed that nearly every child, 97.5% as presented in Table 9, was able to draw a correct representation of the ammonite, either as an animal, or as a fossil (Fig.10). It is remarkable that some students added explanatory details in their drawings and some of them included a prehistoric sea background.

1. Τί είναι ο αμμωνίτης; Είναι ένα αρχαίο ζώο της
 1. What is an ammonite? θαλάσσης που δεν ζει πια. Όπως οι δεινόσαυροι
It is an ancient sea animal, that does not live any more, like dinosaurs.

2. Σχεδιάζω έναν αμμωνίτη: 2. Draw an ammonite:



3. Why do we find ammonites in the Greek mountains?
 3. Γιατί στην Ελλάδα βρίσκουμε απολιθώματα της θάλασσας επάνω σε βουνά;
γιατί παλιά πριν τους και όχι βουνό.
Because that long ago, there was the sea bottom and not a mountain.

Figure 10. Correct post-test answers and representation of an ammonite, by a 4th grader.
 (English translation is added in the original picture.)

Frequencies presented in table 9, reveal that the representations of 4th grade students were as successful as 5th and 6th graders.

Table 9. Frequencies of the students' post-test representations of an ammonite.

Representations of an ammonite	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
Correct representations	176	96.7	181	97.3	187	98.4	544	97.5
Incorrect representations	6	3.3	5	2.7	3	1.6	14	2.5

The 2nd post test question proved to be far more challenging and difficult, as it requested not only a recall of information, but also an ability to connect the ammonites with the regional dynamic geo-environment. As presented in Table 10, less than the half of the students gave correct answers to that question. The 44.1% of the students gave answers that connected the presence of ammonite fossils in Greek mountain rocks with the fact that Greece was the bottom of a prehistoric sea at that geological time. Answers of higher grade students proved better than the lower ones.

Table 10. *Frequencies of the students' answers to the 2nd post-test question.*

Answers to the question: "Why do we find ammonites in the Greek mountains?"»	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
Correct answers	65	35.7	84	45.2	97	51.0	246	44.1
Incorrect answers/no answer	117	64.3	102	54.8	93	48.9	312	55.9

Nearly one third of the students didn't answer at all and the rest of the incorrect answers revealed interesting misconceptions, grouped in three categories and presented in Table 11.

Table 11. *Frequencies of the incorrect student's answers, to the 2nd post-test question.*

Answers to the question: "Why do we find ammonites in the Greek mountains?"»	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %	Frequency (f)	Percentage %
	4 th grade		5 th grade		6 th grade		All students	
Earthquakes	42	35.9	39	38.2	46	49.5	127	40.7
Weather	16	13.7	24	23.5	29	31.2	69	22.1
Sea level	4	3.4	8	7.8	9	9.7	21	6.7
No answer	55	47.0	31	30.4	9	9.7	95	30.4

Many students (40.7%) claimed that earthquakes and tsunamis moved the marine rocks, including fossils, from the sea to the top of the mountains. Also a significant number of answers (22.1%) rationalized the presence of marine fossils in mountain rocks, using meteorological phenomena, such as strong wind, hurricanes, and rainstorms. Finally, the 6.7% claimed that the sea withdrew, the sea level descended and marine fossils finally appeared at the top of the mountains. Students seem to easily confuse geological, meteorological and climatic change phenomena. The construction of their reasoning, shows they used their own experiences and previous frameworks. The students' answers at this point of Step E, showed that the infusion model was not able to replace their alternative ideas with the correct scientific approach. It is widely accepted that these non-scientific beliefs, are often persistent and likely to reappear. As Rule (2005) reported, referring to misconceptions about fossil fuel, they even can be carried into adulthood.

Conclusions

Regarding the evaluation of the model's application, the primary goal, as described in Step B, can be considered mostly, but not fully achieved. The 1st post-test answers and drawings prove that after model application, students did become familiar with the ammonites and know some correct and scientific information about them. Greek students, who participated in the study, seem now to realize that ammonites dominated their region at the time, that dinosaurs dominated other areas of our planet. It is very important that nearly every child represented an ammonite successfully. Findings of the present study, also point out that the misconception, about ammonites and nautilus being the same animal, seems eliminated.

Regarding the additional goals of Step B, the model application did help students build a basic vocabulary and knowledge about the Greek geo-environment, as this appears in their post-test answers. Students' answers and reactions showed an understanding of what paleontology and geology are about, but their connection to other sciences, does not appear clear to them. After model application, many students mention that ammonites can now be found only as fossils and have gone extinct, something that shows they understand that the environment is a constantly changing system. However, their answers to the 2nd post-test question prove that this is not an in depth understanding. Only one third of the students managed to combine the change to the regional environment with the presence of marine fossils in mountain rocks. Students' belief that the Earth's surface is something stable is mentioned in Kusnick (2002) as well. Despite the fact that the teaching material provided them the information that: (i) Greece at that time was a part of Tethys Sea and (ii) that ammonites were the dominant marine habitats of that time, most of the students did not manage to make the appropriate connection or clearly express it. On the contrary, most of the students tried to rationalize that fact, by their own alternative ideas. These findings are in agreement with Happs, who claims that students were also not able to connect plate tectonics with orogenesis. (Driver et. al, 2000) Though students definitely seem to realize that ammonites refer to a past geological period and more than half of them include that in their post-test answers, they do not fully comprehend and imagine the geological time. This is in agreement with Truscott et al. (2006) who stresses out the difficulty of conceptualizing "geological time" or "deep time", as it is a threshold concept not related to everyday situations.

To sum up, the above application of the infusion model seems sufficient for a primary acquisition with this specific topic, but not for an in depth understanding of the whole Greek geo-environment. A possible alternative, towards this direction would be a more extended model application. This could be done, for example, by applying it in more than three lessons of the school curriculum or by using more than one activity/exercise in each lesson. The outcome of this study indicates, that this would preferably be done in 6th graders, whose connections and understanding of the dynamic system proved more efficient. Nevertheless, and besides gaining and applying new knowledge, very important was the motivation, interest, enthusiasm and positive attitude of students and teachers, cultured towards this "unknown" topic.

Implications for more research and work

This study intends to lay the groundwork for future work in geoscience education research and geoscience curriculum development in Greece. A first worthwhile effort would be to do more research in Greek students' views, possible misconceptions in other specific geoscience topics (e.g.: petrified forests), and furthermore in understanding the similarities and differences between relevant geoscience topics, such as rocks and minerals, rocks and fossils. Further research on serving and pre serving teachers' beliefs in

fossils and ammonites would be interesting and helpful, in order to produce geoscience teaching material for the Greek elementary schools. More suggestions, in order to introduce whole specific chapters about the Greek geo-environment, including ammonites and marine fossils in the Greek national curriculum are necessary. Lessons or whole geoscience chapters could more easily be added, in «Geography», «Environmental science» or «Projects' zone», textbooks that are already used in Greek primary schools at the moment.

The fact, that Greece is an active tectonic area, with volcanoes, petrified forests, caves and significant geosites all over it, reinforces our claim that geoscience education should be included in the national curriculum. The above infusion model approach can only partly replace geosciences absence and be considered as an achievable, quick and “price performance” practice, under given circumstances and reality in Greek schools. Scheduled visits to geoscience museums or field trips to relevant geosites could complete, in the best way, the in-classroom teaching. Such geosites can be found all over Greece mainland and islands, thus not all of them are open to public and well organized for school trips. These topics, like ammonite fossils, can as well be considered an ideal starting point for regionally oriented geoscience education.



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